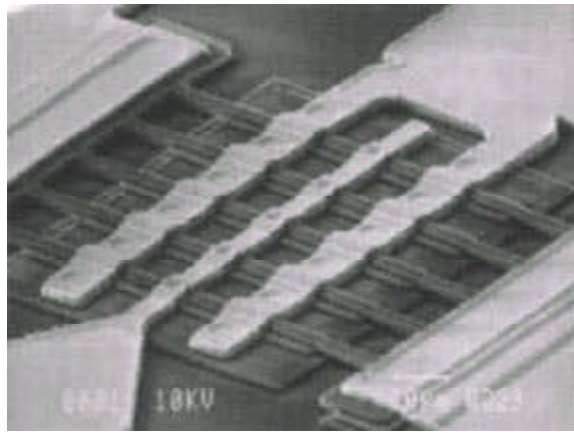


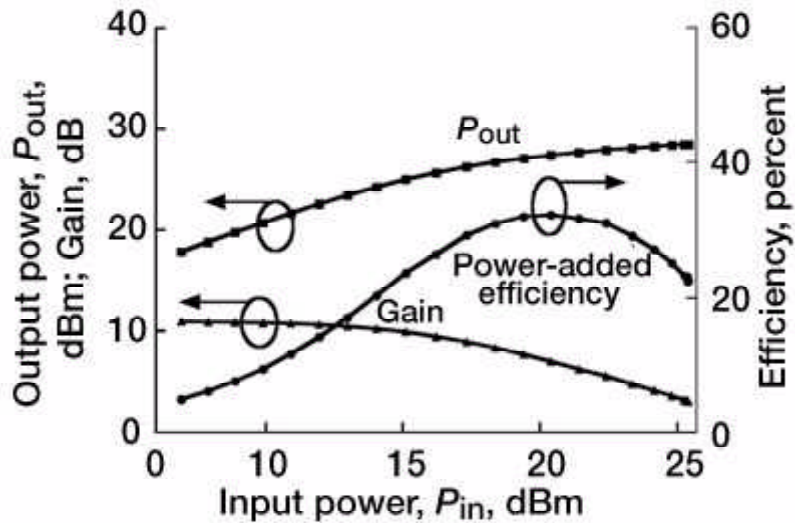
# High-Power, High-Frequency Si-Based (SiGe) Transistors Developed

Future NASA, DOD, and commercial products will require electronic circuits that have greater functionality and versatility but occupy less space and cost less money to build and integrate than current products. System on a Chip (SOAC), a single semiconductor substrate containing circuits that perform many functions or containing an entire system, is widely recognized as the best technology for achieving low-cost, small-sized systems. Thus, a circuit technology is required that can gather, process, store, and transmit data or communications. Since silicon-integrated circuits are already used for data processing and storage and the infrastructure that supports silicon circuit fabrication is very large, it is sensible to develop communication circuits on silicon so that all the system functions can be integrated onto a single wafer. Until recently, silicon integrated circuits did not function well at the frequencies required for wireless or microwave communications, but with the introduction of small amounts of germanium into the silicon to make silicon-germanium (SiGe) transistors, silicon-based communication circuits are possible. Although microwave-frequency SiGe circuits have been demonstrated, there has been difficulty in obtaining the high power from their transistors that is required for the amplifiers of a transmitter, and many researchers have thought that this could not be done.



*Scanning electron micrograph of a silicon-germanium heterojunction bipolar transistor.*

The NASA Glenn Research Center and collaborators at the University of Michigan have developed SiGe transistors and amplifiers with state-of-the-art output power at microwave frequencies from 8 to 20 GHz. These transistors are fabricated using standard silicon processing and may be integrated with CMOS integrated circuits on a single chip. A scanning electron microscope image of a typical SiGe heterojunction bipolar transistor is shown in the preceding photomicrograph. This transistor achieved a record output power of 550 mW and an associated power-added efficiency of 33 percent at 8.4 GHz, as shown in the graph. Record performance was also demonstrated at 12.6 and 18 GHz.



*Measured output power, gain, and power-added efficiency of a 20-finger SiGe heterojunction bipolar transistor. Optimum source impedance,  $G_s$ ,  $0.816 < 180.2^\circ$ ; optimum load impedance,  $G_L$ ,  $0.828 < 149.5^\circ$ ; frequency,  $f$ , 8.4 GHz; collector-base voltage,  $V_{CB}$ , 7.0 V; emitter-base voltage,  $V_{EB}$ , 1.481 V.*

Developers have combined these state-of-the-art transistors with transmission lines and micromachined passive circuit components, such as inductors and capacitors, to build multistage amplifiers. Currently, a 1-W, 8.4-GHz power amplifier is being built for NASA deep space communication architectures.

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